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The O_2 nightglow in the Martian atmosphere by SPICAM onboard of Mars-Express

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1. Introduction

In contract to the dayglow of oxygen in 1.27 µm band on Mars which comes out of ozone photolysis and has been detected for a long time ago, the nightglow is expected in two times less intensive [1,2]. The nightglow is a product of oxygen recombination formed by dayside CO_2 photolysis at the altitudes higher than 70 km and transported on the nightside by the Hadley circulation.
The first possible detection of the emission has been performed by Krasnopolsky [1] in 2003, but the wide field of view during the ground-based observations prevented from the sure detection of the nightside emission by oxygen recombination. Krasnopolsky has concluded that a residual dayside emission can contribute a lot in the observed airglow due to a long lifetime of excited oxygen atoms. The first direct observation of the day-side emission were provided at limb geometry by the OMEGA spectrometer on the Mars-Express orbiter (3 vertical profiles have been detected [3-4], confirmed in the CRISM experiment on Mars-Reconnaissance-Orbiter [5]. All observations related to southern and northern Poles at polar night. The observation of the nightglow at poles is quite important due to it can relate to poorly constrained meridional transport into the polar atmosphere. Moreover the O_2 emission allows to retrieve the atomic oxygen profile at altitude of the emission formation.

2. Observations

The SPICAM IR sounds the Martian atmosphere in the near-IR range (1-1.7 µm) with the spectral resolution of 3.5 cm^{-1} since January 2004 [6]. It measures the O_2 emission with rather high spectral power (~2200) and has obtained the first seasonal map of the oxygen emission on the dayside of Mars [7]. FOV of spectrometer at nadir and limb is 1°. Unfortunately, the nightglow observations at limb require a special command for the device which has been applied only in 2010 specially to search and to map the emission on the night-side. Similar measurements will allow a continuous study of processes in the polar regions of Mars by means of Mars-Express, begun in OMEGA experiment due to the OMEGA cannot more observe the emission in this spectral range. In 2010 SPICAM IR obtained the vertical profiles of the emission near the South Pole at latitudes of 82-83°S for two sequences of observations: L_s=111-120° and L_s=152-165° (table 1).

Table 1. The geometry of limb observations performed by SPICAM in stellar occultation mode where vertical profiles of the nightglow have been obtained.

Orb	Lon	Lat	LT	μ_0	L_s	D_{limb}, km	O_2, MR
8308	103	-83.3	8.11	110	111	2310	0.220
8340	73	-83.2	7.93	109	115	2168	0.250
8374	197	-83.0	7.69	108	120	2025	0.194
8598	333	-82.4	5.84	102	152	1379	0.344
8628	146	-82.3	5.59	100	157	1347	0.391
8654	7.6	-82.2	5.40	99	161	1349	0.277
8679	333	-82.1	5.32	98	164	1394	0.385

3. Results and discussion

For the first sequence of observation around L_s=115°, the $O_2(a^1\Delta_g)$ emission integrated along the slant tangent line of observation has a maximum at ~41-43 km. The altitude of this maximum does not vary much from one orbit to the other. The vertical distribution of $O_2(a^1\Delta_g)$ calculated from this slant emission shows a maximum at 48-52 km. On the contrary, the season of L_s=164° has shown considerable variations of an altitude of the maximum and emission values at the almost same distance to limb of the planet. The altitude of the slant emission maximum varies from 38 to 50 km, and distributions of oxygen molecules vary from 44 to 60 km. As the emission is a result of atomic oxygen recombination in descending branch of the

Hadley cell, it should be strongly sensitive to a transport of these atoms to the polar region of Mars. In this connection a comparison of the received profiles with the three-dimensional general circulation model of Mars including the photochemical block is important.

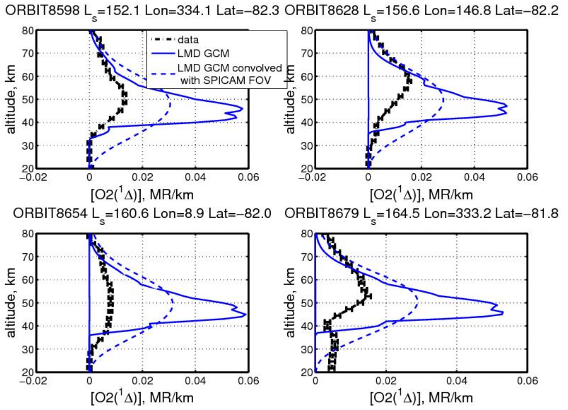

Figure 1. Comparison of the $O_2(a^1\Delta_g)$ vertical profiles with the Martian general circulation model. Lines with errorbar are the SPICAM IR observations; the solid lines are model profiles; dashed lines are model profiles convolved with SPICAM vertical resolution (~20 km for these orbits).

We have compared the $O_2(a^1\Delta_g)$ vertical profiles retrieved from SPICAM to those calculated by the LMD general circulation model with interactive photochemistry [8] (fig.1). The altitude of the emission maximum coincides well with observations only for orbits 8598 and 8654. The absolute values of the model in 2-3 times exceed the values, received by SPICAM IR (fig.2). Lower emission values have been also received at the first observation of the emission by the OMEGA experiment [4]. For L_s~120^o and latitude of 76.5^o of southern latitude the vertical emission was equal 0.24 MR that confirms low values obtained in our observations. Unfortunately, the dataset is insufficient to search longitudinal variations and especially latitude distributions which is very important for meridional transport.

Quantitative estimations of atomic oxygen density have been done at altitudes of 40-70 km. The O density varies from $1.5\cdot10^{11}$ cm^{-3} at altitude of 50 km to 3.5-4.5 10^{11} cm^{-3} at altitude of 65 km that consists well with modeling values at 45 and 65 km and below in 2 times at altitudes of 45-55km. The basic uncertainty in retrieved atomic oxygen profiles is introduced by 2 coefficients: the effective yield and reaction rate for oxygen recombination with strong temperature dependence. One more uncertainty is the unknown temperature and density in atmospheres. The comparison of SPICAM UV T-p profiles and modeling profiles shows a disagreement up to 30K at 50 km for polar region.

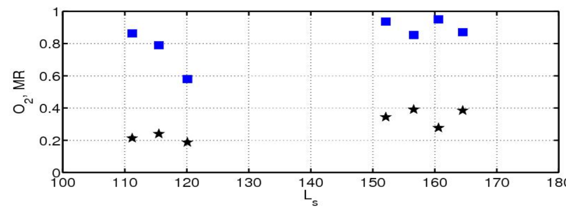

Figure 2. Vertical intensity of the $O_2(a^1\Delta_g)$ nighttime emission versus the areocentric longitude of the Sun. The stars mark observations, squares mark modeling values.

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